

**METHOD AND APPARATUS FOR POWER  
CONNECTION IN A MODULAR PATIENT CARE SYSTEM**

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**CROSS REFERENCE TO RELATED APPLICATIONS**

*See A1*  
*which* ~~This application is a continuation in part of U.S.~~

10 Patent Application Serial No. 08/403,503, entitled "Modular *now US Pat*  
Patient Monitoring and Infusion System," filed March 13, 1995 *5,713,856*  
and assigned to the assignee of the present invention. The  
subject matter of U.S. Patent Application Serial No.  
~~08/403,503 is incorporated herein by reference.~~

15 This application also contains subject matter related to  
copending U.S. Pat. App. Ser. No.        /        filed         
entitled "Method and Apparatus for Logical Addressing in a  
Modular Patient Care System," both assigned to the assignee  
of the present invention. The subject matter of this  
20 application is also incorporated herein by reference.

**FIELD OF THE INVENTION**

The present invention relates generally to modular  
patient care systems. More specifically, the present  
25 invention relates to modular connection arrangement wherein  
modules are detachably connected to each other in a  
convenient, flexible, interchangeable, and secure manner.  
Additionally, the present invention relates to a scheme for  
flexibly, bilaterally, and safely providing electrical power  
30 from a central management unit to attached peripheral units.

**BACKGROUND OF THE INVENTION**

Systems containing multiple infusion pumping units,  
35 sensing units such as blood pressure monitors and pulse  
oximeters, and other patient-care units are known in the

medical field. For example, Kerns et al (U.S. Pat. No. 4,756,706; "Kerns") discloses a centrally managed pump system in which pump and monitoring modules are selectively attached to a central management unit. The central management unit  
5 controls the internal setup and programming of the attached modules, and receives and displays information from them. Each module is capable of being detached from the central management unit except for the first module, which is permanently attached. Once attached and programmed, a module  
10 which is subsequently detached is still capable of operating independently of the management unit.

Kerns provides for attachment of the modules in a vertical stacking sequence in a manner similar to that shown in Figure 1. Attachment of an additional unit to the modular  
15 patient care system involves a multiple step process. These steps include (1) sliding a support plate 62 of the additional unit into the channel 64 of a previous unit, and (2) turning a knob 120, causing male connectors 122 and 124 of the additional unit to pop up and mate with corresponding  
20 female portions in the previous unit (Kerns Fig. 3 and col. 4 lines 7-16). Thus, achieving mechanical and electrical connectivity in Kerns clearly involves a multi-step, two-handed operation.

Further, Kerns provides for distinct, direct electrical  
25 connectivity from each stack module to the central management unit. Each module is provided with a separate AC power signal from the central management unit AC+ and AC- leads. Each module also contains its own power supply for autonomous operation when disconnected from the central management unit  
30 (Kerns Fig. 6).

Kerns has several disadvantages. First, for electrical and mechanical connectivity of an added unit to the central management unit, a multi-step, two-handed operation is needed, which may be cumbersome and time consuming in the  
35 medical environment. Second, because each module requires its own set of electrical paths to the central unit, the total number of modules which may be stacked is only one

greater than the number of pass-through cables in each module. For example, for the pass-through structure shown in Kerns Fig. 4f, only four modules total may be accommodated by a system which uses these modules. Third, there is added weight, cost, and complexity due to the multiple cabling structure. For example, each signal of each cable must have its own contact pin in among the pins 122 of the contact structure of Kerns Fig. 3. Finally, the presence of a power supply in each functional module adds weight and cost.

- 10 Rubalcaba (U.S. Pat. No. 4,898,578) also discloses a drug infusion system which includes a plurality of infusion pump modules selectively attached to a central management unit so as to provide for centralized control. In particular, the central management unit obtains infusion  
15 parameters from the user and then performs calculations with the parameters to establish the desired infusion rate. Once this rate is determined, the central management unit may control the infusion accordingly. Rubalcaba, however, provides no solution for the problems related to electrical  
20 and mechanical connectivity of units described above with respect to Kerns.

Accordingly, it is an object of the present invention to provide a modular patient care system wherein modules are detachably connected to each other in a convenient, flexible,  
25 interchangeable, and secure manner.

It is another object of the present invention to provide a modular patient care system wherein each functional unit is powered by the central management unit using a common power bus scheme to avoid a multiplicity of power lines.

- 30 It is a further object to provide a flexible, bilateral power scheme wherein any functional unit may be placed anywhere in a linear array of units and be adequately powered. It is a further object of the present invention to make this powering scheme safe by avoiding active power  
35 supply voltages at exposed ends of the power bus.

## SUMMARY OF THE INVENTION

These and other objects of the present invention are provided in a modular patient care system comprising an interface unit for providing a user interface to the system  
5 and for providing electrical power to at least one functional unit, the functional unit being capable of removable connection to the interface unit for providing patient therapies or monitoring the condition of the patient, the functional unit being for removable attachment to the  
10 interface unit or other functional units so as to form a linear array of units. The linear array of units comprises an originating end and a terminating end, and each unit has an originating side and a terminating side, the originating side of any unit being capable of removable connection to the  
15 terminating side of any other unit. In one embodiment, the originating side is the left side, and the terminating side is the right side of the linear array.

The interface unit according to the present invention has a left power lead for powering left side functional  
20 units and a right power lead for powering right side functional units. Power supply aspects of the left and right sides are substantially symmetric. Using the left side as an example, power supplying aspects of the interface unit are arranged so as to connect power to the left power lead when  
25 functional units are attached to the left, but to leave the left power lead electrically isolated when no functional units are attached to the left. This prevents the unsafe and insecure situation of a live voltage existing at an exposed left power lead of the linear array of units, which would be  
30 subject to shorting out or otherwise undesirably discharging. To accomplish this objective, the interface unit includes a power source for receiving electrical power from a power supply and providing electrical power, a detecting lead for detecting the presence of a right sense signal, such as a  
35 ground signal, from a unit attached to the left, means for coupling the power source to the left power lead in the

presence of the right sense signal, and means for decoupling the power source from the left power lead in the absence of the right sense signal. In one embodiment, the detecting lead is connected to a gate of a field effect transistor, the power source is connected to a drain of the field effect transistor, and the left power lead is coupled to a source of the field effect transistor.

A flexible, bilateral, and safe powering scheme in the modular patient care system according to the present invention is also provided for by providing an exemplary functional unit having a left lead and a right lead, the left lead for contacting the right lead of a left adjacent functional unit or the right power lead of the left adjacent interface unit in the linear array, the right lead for contacting the left lead of a right adjacent functional unit in the linear array or the right power lead of the right adjacent interface unit in the linear array. The functional unit has a load unidirectionally coupled to the left and right leads and capable of receiving electrical power from either of the leads. The functional unit also has a right sense signal lead for providing a right sense signal to the adjacent right unit, if any, and a left detect lead for detecting the right sense signal from the adjacent left unit, if any. Further, the functional unit also has a left sense signal lead for providing a left sense signal to the adjacent left unit, if any, and a right detect lead for detecting the left sense signal from the adjacent right unit, if any. Finally, the functional unit comprises means for bidirectionally connecting the left power lead to the right power lead only upon detecting both left and right signals.

In this manner, a functional unit which is located between two other units in the linear array is capable of powering its load while also passing power, in either direction as needed, to the adjacent unit which is located farther away from the interface unit. However, if the functional unit is located at the left end of the linear array, the left power lead remains electrically isolated

because no right sense signal is detected. Likewise, if the functional unit is located at the right end of the linear array, the right power lead remains electrically isolated because no left sense signal is detected. In this manner,  
5 the functional units are capable of flexible, bilateral power connection in the linear array of units, and live power contacts are prevented from existing at the leads located at the ends of the linear array of units for safety and security.

10 In another embodiment of the invention, a modular patient care system is provided having an interface module for providing a user interface to the system and at least one functional module capable of removable connection to the interface module. The functional module is for providing  
15 patient therapies or monitoring the patient's condition and is capable of removable attachment to the interface module or other functional modules so as to form a linear array of modules. The linear array of modules comprises an originating end and a terminating end, and each module has an  
20 originating side and a terminating side, the originating side of any module being capable of removable connection to the terminating side of any other module.

Physically, an exemplary functional module according to the present invention comprises a first portion grippable by  
25 a user and is configured and dimensioned so as to be capable of being held by a single hand of the user by gripping the first portion. Any pair of modules, including for example the interface module and the exemplary functional module, are easily, flexibly, and interchangeably coupled by including a  
30 hinge connector pair for allowing hingeable engagement of the pair, a latch mechanism for securing the pair together, and a guide mechanism located between the hinge connector pair and the latch mechanism for discouraging off-axis engagement of the modules and for providing mechanical stability to the  
35 engaged pair. The latch mechanism is designed to automatically secure the pair together, such that engagement of the modules takes place in a single-handed, single step

operation, but is designed to require a manual operation by a hand separate from the hand gripping the first portion to unlatch the modules during disengagement. This provides for increased security and prevention of accidental disengagement of modules. Preferably, the latch mechanism springably couples together such that tactile feedback is provided to the user during attachment. An optional fastener for fastening the latching mechanism together may be included, which requires a special tool for unfastening the latching mechanism so as to further increase system security at the option of the user.

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a front view of a multi-module electronic system wherein the individual modules are interconnected electrically and structurally in accordance with the present invention;

FIG. 2 shows an oblique view of two modules showing structural and electrical features for module connection in accordance with the present invention;

FIG. 3a shows a front view of the modules shown in FIG. 2 positioned for subsequent engagement with each other, with portions broken away to reveal the connection scheme according to the present invention and associated electronic components;

FIG. 3b shows the modules of FIG. 3a after engagement;

FIG. 4 shows an exploded perspective view of a single module showing the interconnector parts of the present invention enlarged and out-of-scale;

FIG. 5a shows a bottom view of a pair of engaged modules in accordance with an embodiment of the present invention;

FIG. 5b shows a front cut-away view of the modules of FIG. 5a to reveal a latching and locking scheme in accordance with an embodiment of the present invention;

FIG. 6 shows a functional diagram of the power provision features of the interface unit according to the present invention;

FIG. 7 discloses a functional circuit diagram of the bilateral powering features of a functional unit in accordance with the present invention; and

FIG. 8 shows a functional diagram of the unit detection and power features of a modular patient care system in accordance with the present invention.

#### DETAILED DESCRIPTION OF THE INVENTION

The following embodiments of the present invention will be described in the context of a modular patient care system, although those skilled in the art would recognize that the disclosed methods and structures are readily adaptable for broader application. Note that whenever the same reference numeral is repeated with respect to different figures, it refers to the corresponding structure in each figure.

FIG. 1 discloses a modular patient care system 100 in accordance with the present invention. Modular patient care system 100 comprises a plurality of modules or units, including interface unit 102 and functional units 104, detachably coupled to each other to form a linear array. Shown in FIG. 1 are exemplary functional units 104A, 104B, 104C, and 104D coupled to interface unit 102. While four functional units are shown in FIG. 1, a modular patient care system in accordance with the present invention may comprise interface unit 102 coupled to only a single functional unit 104, or may comprise interface unit 102 coupled to as many as "N" functional units 104.

Interface unit 102 generally performs the functions of (1) providing a physical attachment of the system to structures such as IV poles and bedrails, (2) providing electrical power to the system, (3) providing an interface between the system and external devices, (4) providing a user interface to the system, and (5) providing overall system control, which includes providing information to and receiving information from functional units 104. Shown in FIG. 1 are certain user interface aspects of interface unit



102, which may include an information display 106, numerical hardkeys 108, and softkeys 110.

Functional units 104 are generally for providing patient therapies or monitoring responsive to information, at least 5 some of which may be received from interface unit 102. In many cases, functional units 104 are also for communicating information to interface unit 102. For example, functional unit 104A may be an infusion pump unit for delivering fluids to a patient responsive to certain commands received from 10 interface unit 102, while functional unit 104B may be a blood pressure monitoring unit for providing patient blood pressure information to the interface unit 102. The scope of the invention is not so limited, however.

For the purposes of the present invention, the specific 15 function of each individual functional unit 104 is not critical. Rather, the present invention is directed toward (1) the mechanical and electromechanical coupling of the functional units 104 to each other and to interface unit 102, and (2) the electrical powering scheme of the modular patient 20 care system 100. Thus, for purposes of understanding the present invention, it is important only to recognize that functional units 104 (1) require means for detachably coupling to each other and to interface unit 102, and (2) require electrical power.

25 In a preferred embodiment of the present invention, interface unit 102 and functional units 104 are laterally interchangeable. By laterally interchangeable, it is meant that the modules may be placed in any order in forming a linear array of modules. Thus, in FIG. 1, the modular 30 patient care system 100 may instead have its modules ordered left-to-right in the sequence 104C, 102, 104B, 104D, 104A without affecting its functionality. In order to be laterally interchangeable, the units 102 and 104 of FIG. 1 should have substantially identical interconnection features 35 on their respective left sides, and should have corresponding substantially identical interconnection features on their right sides. If the units were instead for coupling in a

vertical linear array, which is within the scope of the present invention, the interconnection features would have substantially identical interconnection features on their respective top sides, and would have corresponding

5 substantially identical interconnection features on their bottom sides. For clarity of explanation, however, only a left-to-right physical arrangement is described.

To achieve the lateral interchangeability described above, each of the units 102 and 104 should also have power,  
10 unit detection, and communication circuitry which is complementary. By complementary, it is meant that the units 102 and 104 generally have power, unit detection, and communications circuit contacts on a first side and on a second side, and that the first side contacts of one unit may  
15 be connected to corresponding second side contacts of any other unit, with the overall linear array of units comprising modular patient care system 100 being fully operational. In FIG. 1, for example, the first side of a unit is the left side, and the second side of a unit is the right side.  
20 Further to this example, and as further explained later, functional unit 104C must be capable of receiving electrical power from interface unit 102 to its left and transferring it to unit 104D to its right; yet, if physically interchanged with functional unit 104B, unit 104C must be capable of  
25 receiving electrical power from interface unit 102 to its right and transferring it to unit 104A to its left, and so on.

As shown in FIG. 1, each functional unit 104 may include a unit ID indicator 112 which identifies a logical address of  
30 the functional unit within the linear array. The logical address of a functional unit 104 indicates its position in the linear array relative to other functional units 104. The logical address of a functional unit 104, such as unit 104B, is used by the interface unit 102 to identify and uniquely  
35 communicate with functional unit 104B in a common communications bus environment to be described later. In a preferred embodiment of the invention, the logical address of

a functional unit corresponds to its sequential position in the linear array of functional units. Thus, the system shown in FIG. 1 may illustratively contain functional units 104A-104D with logical addresses A, B, C, and D, ordered left to right. In this embodiment, the left side of the leftmost unit forms an originating end of the linear array, while the right side of the rightmost unit forms a terminating end of the linear array.

Referring now to FIGS. 2 through 4, the mechanical and electromechanical aspects of interface unit 102 and functional units 104 as designed in accordance with a first embodiment of the present invention are now described. For purposes of the first embodiment of the present invention, interconnection features of interface unit 102 are substantially identical to interconnection features of functional units 104. Therefore, only an exemplary unit 104A will be described. Also, an exemplary unit 104B, substantially identical to unit 104A and for connecting thereto, will be described when needed for clarity.

FIG. 2 shows an oblique representation of exemplary units 104A and 104B positioned before being matably connected, while FIGS. 3a and 3b show appropriate cut-away views of units 104A and 104B during and after the connection process, respectively.

As shown in Fig. 2, unit 104A comprises a chassis 200 having a left side 202, a front 204, and a right side 206. It is to be appreciated that although Fig. 2 shows numbered components on units 104A and 104B according to their visibility in the oblique drawing, the units 104A and 104B contain substantially identical numbered components. Unit 104A further comprises a male connector portion 208 on right side 206, a female connector portion 210 on left side 202, a male elevation feature 212 formed on right side 206, a female recess feature 214 formed in left side 202, a catch feature 216 formed near the bottom of right side 206, and a latch 218 near the bottom of left side 202. Unit 104A further comprises cover 220 tethered to male connector portion 208

for covering the male connector portion 208 during periods of non-use, and pocket 222 formed in right side 206 near male connector portion 208 for receiving cover 220 otherwise.

Unit 104A further comprises cover 224 tethered to female  
5 connector portion 210 for covering female connector portion 210 during periods of non-use, and pocket 226 formed in left side 202 near female connector portion 210 for receiving cover 220 otherwise.

Generally, as shown in FIGS. 3a and 3b, units 104A and  
10 104B are designed to be connected using the steps of (1) tilting the units relative to each other while inserting male connector portion 208 into female connector portion 210, (2) swinging down the units to a nearly parallel position such that male elevation feature 212 is received into female  
15 recess feature 214 and latch 218 is received into catch feature 216, and (3) pressing the units together such that latch 218 is locked into catch feature 216.

Male connector portion 208 of unit 104A is positioned and formed for hingeable connection with female connector  
20 portion 210 of unit 104B for achieving mechanical and electrical coupling of units 104 and 105. In a preferred embodiment of the invention, male connector portion 208 and female connector portion 210 also form a 15-pin electrical connector pair for electrically coupling. This electrical  
25 connector pair is for electrically coupling electronic components contained in units 104A and 104B, these electronic components being shown generally as elements 300 in FIGS. 3a and 3b. The geometry of male connector portion 208 and female connector portion 210 include lead-in and chamfer to  
30 reduce the probability of dropping and off-axis insertion. Advantageously, the geometry of the male-female pair is designed to prevent a unit from falling off if it is hooked but not yet latched. The mechanical characteristics of the male-female pair are detailed in U.S. Patent Application  
35 Serial Number 08/403,502, cross-referenced above.

Male elevation feature 212 is formed on right side 206 of unit 104A for mating with female recess feature 214 formed

in left side 202 of unit 104B to provide multiple contact surfaces for improved front to back stability during vibration of the connected units. Further, the geometry of male elevation feature 212 includes lead-in and chamfer for  
5 mechanical guidance into recess feature 214 such that the probability of off-axis insertion is reduced.

Latch 218 is for engaging a catch feature 216 during connection. This keeps the units together mechanically after attachment. In a preferred embodiment, latch 218 is spring  
10 loaded with a pre-load force sufficient to positively engage the catch feature 216, close, and remain latched unless disengaged by an operator. Also in a preferred embodiment, techniques known in the art may be used to shape latch 218 and catch feature 216 such that a small vibration resonates  
15 through units 104A and 104B upon attachment, to provide tactile feedback to the user.

Cover 220 is for covering male connector portions 208 during transport and periods of non-use. In a preferred embodiment of the invention, cover 220 is made of an  
20 elastomeric material which is elastic and waterproof. Cover 220 is tethered to male connector portion 208 to reduce the possibility of being lost or misplaced by the user, and is dimensioned and configured to be swung up and over male hook feature 208 for protection. Pocket 222 is formed in right  
25 side 206 beneath male connector portion 208 for receiving cover 220, which nests into pocket 224 when not in use. Cover 220 may be swung up out of pocket 222 to cover male connector portion 208 to protect connector portion 208 from dust or fluids. Similar purpose, material, and  
30 configurations apply to cover 224 and pocket 226.

Advantageously, the covers 220 and 224 and pockets 222 and 226 are configured and dimensioned such that the covers recess flush yet are partially compressed when the units 104A and 104B are attached, thus providing additional shock  
35 cushioning and preventing rattling during vibration or transport.

In a preferred embodiment of the invention, the size and geometry of unit 104A is generally such that it may be held by a single hand of a user, although the invention is not necessarily so limited. This is generally the same user hand  
5 which receives the tactile feedback described above upon unit attachment.

FIG. 4 shows a view of unit 104A exploded to more succinctly show male connector portion 208 and female connector portion 210 with respect to a preferred embodiment  
10 of the invention. Specifically, male connector portion 208 comprises electrical contacts 400 contained on a curved lip 404 formed on a body portion 406. Further, female connector portion 210 comprises electrical contacts 408 protruding into an aperture 410 formed in body portion 412. In a preferred  
15 embodiment of the invention, the contact geometry and orientation of electrical contacts 400 and 408 may allow a first set of individual electrical contact pairs formed by joining the connectors to make electrical connection prior to a second set of electrical contacts during connection. A  
20 result of this geometry and orientation will be that the first set of contacts will also break after the second set of contacts during disconnection. This ensures, for example, that an electrical ground connection between the units may be made first during module attachment, creating a path to  
25 dissipate electrostatic discharge.

Also in a preferred embodiment of the invention, body portions 406 and 412 are made of a low surface energy/hydrophobic material to shed fluid from exposed surfaces. Also, in a preferred embodiment the electrical  
30 contacts 400 and 408 are insert-molded into body portions 406 and 412, which prevents extraneous fluids from accumulating adjacent to electrical connections.

FIGS. 5A and 5B show units 104A and 104B with additional features in accordance with a preferred embodiment of the  
35 invention. FIG. 5A shows a bottom view of coupled units 104A and 104B. Unit 104B comprises latch 218 for engaging catch feature 216 of unit 104A. In this embodiment however, a

fastener 500 may be employed to provide a means for making the attachment of units 104A and 104B permanent until the fastener 500 is released by a user using a releasing technique. This releasing technique may employ the use of a special tool (not shown) made available only to specified users. FIG. 5B shows a side view of latch 218 engaged to catch feature 216, further showing a latch tongue 502 of latch 218 which forms a hole 504 in an area which overlaps catch feature 216. Fastener 500 which is, for example, a screw, is inserted from the bottom of functional unit 104A near catch feature 216 through hole 504 and into a boss 506 contained in functional unit 104A near catch feature 216. The configuration shown advantageously provides for permanent attachment of the units until a user such as a medical technician disengages fastener 500. In this manner, for example, miscellaneous persons around and in the area of the modular patient care system 100 are prevented either from intentionally or accidentally causing disconnection of units.

The unique combination of the module elements described thus far provide for many advantages in stability, safety, security, and ease of use. For example, the attachment of a functional unit may be achieved in a one hand, single step operation, while the presence of latch 218 and catch feature 216 dictate that detachment must take place in a two step operation. This is advantageous in a medical environment where quick, easy attachment of units to the linear array may be necessary, but where detachment of units should be permissible only upon an explicit, reasoned desire of a user and not by accident. This feature is enhanced as a preferred embodiment of the invention employing a fastener 500, wherein further steps are needed to detach modules.

Further, the ease of the one-handed, single step operation in the attachment of units is enhanced where latch 218 and catch feature 216 provide for tactile feedback during the attachment operation. This is advantageous in the medical environment by freeing up the eyes of the user during attachment to pay attention to more sensitive events taking

place, such as insuring that needles, lines, fluids, or pumps are not being disturbed during the mechanical movement.

Further, the avoidance of the need for visual feedback to the user may save precious moments during medical emergencies

5 when the user's eyes are more advantageously averted to the emergency at hand.

Even further, the presence of male elevation feature 212 mated to recess feature 214 provides for additional front to back stability of the units during handling and abuse. These  
10 features also provide guidance during connection to prevent off-axis insertion. Vibration of coupled units is further reduced by the compression of covers 220 and 224 against each other and pockets 222 and 226.

Even further, several means exist to protect the  
15 electrical connections from fluid ingress when units are not connected. First, the contact geometry, contact orientation, and hook geometry as shown in FIG. 4 prevent fluid from accumulating on surfaces of the male connector portion 208. Similarly, the contact geometry, contact orientation, and  
20 contact location of the electrical contacts 408 prevent fluid from accumulating on surfaces of the female connector portion 210. Use of low surface energy/hydrophobic material for body portions 406 and 412, insert-molding of the contacts 400 and 408, and the presence of covers 220 and 224 further  
25 discourage unwanted fluid accumulation and ingress.

In the modular patient care system 100 of FIG. 1, electrical power is supplied to functional modules 104 by interface unit 102. The interface unit 102, in turn, may be powered by conventional methods known in the art. At least  
30 one electrical power path exists among the electrical contacts 408 and 400 at the connecting point of any two units.

The goal of a module powering system designed in accordance with the present invention is, first, for  
35 interface unit 102 to provide power to any attached module or set of modules by powering immediately adjacent modules. Thus, in FIG. 1, interface unit 102 is to supply electrical



power to all functional units 104 by powering functional units 104B and 104C, which each use a portion of this power and which, in turn, transfer at least a portion of this power further down the line to units 104A and 104D, respectively.

5       Second, the module powering system in accordance with the present invention is to permit lateral interchangeability of the modules, and thus the powering system of any functional unit 104 is to be bilateral. By bilateral, it is meant that the functional unit 104 may receive power from  
10 either its first or second side, and may transmit this power, if necessary, to attached units on its second or first side, respectively.

Third, it has been found that a module powering system according to the present invention is to comprise an  
15 interface unit 102 and functional units 104 which, if they are positioned on the originating or terminating end of a linear array, do not allow a live voltage to exist at the open electrical contacts which will exist at these ends. Such a requirement provides, for example, for added security  
20 of the unit from power failure due to accidental or intentional shorting of the exposed power leads.

Turning now to FIGS. 6 through 8, a module powering system according to a second embodiment of the present invention is described. FIG. 6 shows a functional diagram of  
25 the power aspects of interface unit 102 designed in accordance with the present invention. Interface unit 102 comprises a microprocessor 600, a power source 602, a left transistor 604, and a right transistor 606. Power source 602 is adapted for providing an 8-volt DC voltage by either  
30 generating its own power, as from a DC voltage source such as an internal battery, or for adapting power from an external AC or DC source, as is known in the art. The 8 volts DC provided by power source 602 is provided by lead 607 with respect to the ground plane of interface unit 102, denoted  
35 generally by element 608 in FIG. 6. Interface unit 102 further comprises left and right power leads 610 and 612, respectively, for coupling to and providing power to left and

right adjacent functional units, respectively, when connected. Power leads 610 and/or 612 will be left open, however, when adjacent units are not connected. Interface unit 102 further comprises left and right module detect leads 5 614 and 616, respectively, for detecting the presence of attached functional units on the left and right sides, respectively. Interface unit 102 further comprises ground leads 618 to 620 for providing left and right sense signals, respectively (which in this embodiment are ground signals) to 10 adjacently attached units. It is noted that additional electrical contacts not shown may provide an overall ground plane signal to attached functional units, as is known in the art.

As shown in FIG. 6, lead 607 of power source 602 is 15 coupled to the source of left transistor 604 and also to the source of right transistor 606. In the embodiment shown, transistors 604 and 606 are, in this embodiment, P-channel enhancement MOSFETs. The gate of left transistor 604 is coupled to left module detect lead 614, while the gate of 20 right transistor 606 is coupled to right module detect lead 616. Finally, the drain of left transistor 604 is coupled to left power lead 610, while the drain of right transistor 606 is coupled to right power lead 612.

As shown in FIG. 6, transistor 604 will conduct (i.e., 25 create a "short" between its drain and source) when its gate is low with respect to the source, and will not conduct (i.e., create an "open") when its gate is high. Transistor 606 behaves similarly. Thus, if left module detect lead 614 is grounded by attachment to an external signal, such as a 30 signal provided by an attached functional unit to the left, transistor 604 will conduct, and thus power lead 610 will be coupled to power source lead 607 to provide power. When left module detect lead 614 is left open, as when a unit is not attached to the left, transistor 604 does not conduct and 35 leaves power lead 610 electrically isolated from power source lead 607. This, of course, is a desired result. Similar

characteristics exist for right module detect lead 616, transistor 606, and right power lead 612.

It is noted that the coupling of the left module detect lead 614 to microprocessor 600 at pin MODDETL shown in FIG. 6 does not affect the powering aspects described here, as pin MODDETL is only for detection purposes of the microprocessor for purposes to be described later. A similar note applies to right module detect lead 616 and pin MODDETR of microprocessor 600. Finally, it is noted that Schottky diodes 626 and 628 are provided across the drain and source of transistors 604 and 606, respectively, for protection against reverse voltages, as is known in the art.

FIG. 7 shows a functional diagram of the power aspects of an exemplary functional unit 104A designed in accordance with the present invention. Functional unit 104A comprises a microprocessor 700 and a load 702 such as an infusion pump motor. It is noted that load 702 may represent any kind of electrical system requiring power, however. Functional unit 104A further comprises a left transistor 704 and a right transistor 706. Load 702 receives electrical power provided between an input node 707 and a ground plane, generally denoted by element 708 in FIG. 7. Functional unit 104A further comprises a left power lead 710, a right power lead 712, a left module detect lead 714, a right module detect lead 716, a left ground lead 718, and a right ground lead 720.

As shown in FIG. 7, the drain of left transistor 704 is coupled to the drain of right transistor 706. Transistors 704 and 706 are, in this embodiment, P-channel enhancement MOSFETS. The source of left transistor 704 is coupled to left power lead 710, while the source of right transistor 706 is coupled to right power lead 712. Left power lead 710 is also coupled through a resistor 722 to the left module detect lead 714, which is in turn coupled directly to the gate of right transistor 706. Correspondingly, right power lead 712 is coupled through a resistor 724 to the right module detect lead 716, which is in turn coupled directly to the gate of

left transistor 704. Left power lead 710 is coupled to the cathode of a diode 726 whose anode is in turn coupled to input node 707 of load 702. Likewise, right power lead 712 is coupled to the cathode of a diode 728 whose anode is in turn coupled to the input node 707 of load 702. - In this manner, if a positive power voltage is present at lead 710, power is supplied to load 702 without being supplied to lead 712 unless both transistors 704 and 706 are conductive. Likewise, if a positive power voltage is present at lead 712, power is supplied to load 702 without being supplied to lead 710 unless both transistors 704 and 706 are conductive.

As shown in FIG. 7, transistor 704 will conduct (i.e., create a "short" between its drain and source) when its gate is low with respect to the source, and will not conduct (i.e., create an "open") when its gate is high. Transistor 706 behaves similarly. The gate of transistor 704 will be forced low when right module detect lead 716 is grounded by an adjacent attached unit to the right. Correspondingly, the gate of transistor 706 will be forced low when left detect lead 714 is grounded by an adjacent attached unit to the left. It is noted that Schottky diodes 730 and 732 are provided across the drain and source of transistors 704 and 706, respectively, for protection against reverse voltages, as is known in the art. It is noted that, as described above and as shown in FIG. 7, module 104A forms a laterally symmetric powering arrangement.

As described herein, a modular patient care system 100 comprising the interface unit of FIG. 6 and functional modules according to FIG. 7 advantageously provides for bilateral power sourcing and transfer through the functional modules 104, while providing electrical isolation of power leads of units at the originating and terminating ends, respectively.

FIG. 8 shows the modules of FIG. 6 and FIG. 7 arranged in an exemplary arrangement comprising functional unit 104A at the originating (left) end, functional unit 104D at the terminating (right) end, and units 104B, 102, and 104C in the

middle, respectively. As shown in FIG. 8, the electrical leads between units are arranged according to the following simple scheme. Left power leads (610 or 710) are coupled to right power leads (712 or 612) in any pair of adjacent units.

- 5 Left module detect leads (714 or 614) are coupled to right ground leads (620 or 720) in any pair of adjacent units. Finally, left ground leads (618 or 718) are coupled to right module detect leads (716 or 616) in any pair of adjacent units.

- 10 Serving as an example of a system according to the present embodiment of the present invention, the powering configuration of the modular patient care system 100 shown in FIG. 8 advantageously functions as follows.

- Looking to the left of interface unit 102, lead 720 of  
15 unit 104B grounds the gate of left transistor 704 of unit 102 via module detect lead 614. Transistor 604 is turned on, and power is thus supplied through left power lead 610 of unit 102 to right power lead 712 of unit 104B, thus powering the load 702 of unit 104B. Left ground lead 618 of unit 102  
20 grounds the gate of left transistor 704 of unit 104B through right module detect lead 716, making transistor 704 conductive. Further, right ground lead 720 of unit 104A grounds the gate of right transistor 706 of unit 104B, making transistor 706 conductive. The result is that both of  
25 transistors 704 and 706 of unit 104B are conductive, and thus power lead 712 of unit 104A will receive power from left power lead 710 of unit 104B. Therefore, load 702 of unit 104A will be powered, and thus left side units 104A and 104B are fully powered.

- 30 However, there is no ground signal provided to left module detect lead 714 of unit 104A because it is the leftmost unit. Thus, right transistor 706 of unit 104A remains turned off. The result is that left power lead 710 of leftmost unit 104A is electrically isolated from right  
35 power lead 712, which is the desired result. It should be clear to anyone of ordinary skill on the art, given the lateral symmetry of the powering arrangement described above,

that right side units 104C and 104D operate in a similar but reflexive fashion to the left side units 104A and 104B.

Thus, power is provided to both units 104C and 104D, but right power lead 712 of rightmost unit 104D remains

5 electrically isolated from a power source. This, of course, is the desired result.

Additionally, it should be clear to anyone of ordinary skill in the art that the units 102 and 104A through 104D can be arranged in any order in FIG. 8 with the desired result of

10 (1) powering of all units, (2) electrical isolation of the left power leads 710 or 610 of the leftmost (originating) unit, and (3) electrical isolation of the right power leads 712 or 612 of the rightmost (terminating) unit.

Various embodiments of the invention have been  
15 described. The descriptions are intended to be illustrative, not limitative. Thus, it will be apparent to those skilled in the art that modifications may be made to the invention as described without departing from the scope of the claims set out below.

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